# An analysis of the invasive potential of *Cupressus lusitanica* and its effects on the chemical properties of the surrounding soils


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# ABSTRACT

The purpose of this study was to assess the potential for an introduced cypress, *Cupressus lusitanica,* to become invasive and/or cause significant changes in pH and macronutrient concentrations in the acidic soils of the cloud forests at Cloudbridge Nature Reserve in the Talamanca Mountains of Costa Rica. This was done by comparing the reproduction of *C. lusitanica* to the reproduction of two native species, *Alnus accuminata* and *Ulmus mexicana*. Soil samples were taken from underneath each species and at randomly selected open sites, and then tested for pH and nitrogen, potassium, and phosphorus concentrations.

The study found that there was no significant difference between any site in terms of macronutrient concentration but there was in terms of pH ($F(8, 81)=5.91$, $p=6e\text{-}06$). The cypresses on average had soils one point more basic than the comparison trees and open sites. There was also a weak, positive linear relationship between the soil pH under the sampled cypresses and the trees' DBH, suggesting that the soil pH becomes more basic as the cypress ages.

There was no significant difference in reproduction between the cypress and the native trees; all had very few successful offspring. The classification of *C. lusitanica* as a naturalized, instead of invasive, species in Costa Rica is correct, and the cypress is not much of a threat as it is unlikely to sustain a population on the Reserve for much longer.


# INTRODUCTION

*Cupressus lusitanica*, sometimes called *cedro blanco*, is a cypress from northern Central America and Mexico. It was introduced en masse in Costa Rica in the 1980's for use in erosion control, windbreaks, and lumber plantations, and has quickly become a staple part of the national landscape (Burlingame 2000). Despite it's non-native status, the cypress has also made its way into reforestation and conservation efforts due to it's hardiness as a pioneer species and quick time to grow to maturity (Bol and Vroomen 2008, Lehmann 2006).

Many scientists have expressed concern about the cypress' wide use mainly because it is a foreign species. It is important to note that all the ways that the cypress is used – erosion control, windbreaks, lumber plantations, etc. could conceivably be replaced by native species (Halstead 2008, Lehmann 2006). With that in mind, should the cypress have any detrimental effect on the environment or potential for invasiveness, it would be sensible to remove them.

Conifers in general are known for their ability to chemically alter the environment, specifically by lowering the pH(Bol and Vroomen 2008, Doescher 1987, Halstead 2008, Lemenih 2004), though this correlation is often disputed between studies (Cavelier and Tobler 1998, Wilcox and Davenport 2004). In studies in Columbia and Ethiopia *C. lusitanica* was found to have limited effects on the concentrations of the soil macronutrients nitrogen, potassium, and phosphorus as well as pH. It was also suggested that the cypress may have a rejuvenating effect on worn out agricultural soil (Cavelier and Tobler 1998, Lemenih 2004). If true, these chemical interactions in the soils could have a whole array of lasting effects on the surrounding native flora.

The second concern about the cypress' alienness is it's potential for invasiveness. It has already been established that the cypress grows incredibly quickly, and many anecdotal accounts in Costa Rica tell of planted cypress establishing sapling volunteers around them. These two facts already indicate the cypress has invasive potential (Richardson and Rejmánek 2004), all that is left is to assess the tree's actual amount of reproduction in the field. Tropical forests in general tend to resist the establishment of invasive plants relatively well, but tropical forests that have been disturbed and are regrowing do present an opening for invasive plants to establish themselves (Sheil 1994).

Despite general reservations about the use of the cypress in forest restoration, scientific findings regarding the cypress' effects on the environment and reforestation efforts are not always negative. It has been found that the windbreaks and property line markers made of cypress do in fact attract seed dispersing animals, effectively causing seed rain and the independent regeneration of areas deforested for agriculture (Harvey 2000). However, when compared with more hands on reforesting methods the forests created by seed rain and natural regrowth alone are much less diverse than the primary forests they seek to emulate (Muñiz-Castro 2006).

This study takes place at Cloudbridge Nature Reserve in the Talamanca Mountains outside of San Gerardo de Rivas, Costa Rica. The Reserve is in a tropical, montane, moist forest ecosystem called a cloud forest, named for the persistent fog shrouding the canopy. The area's soils are quite undeveloped, acidic, and low in nutrients due to the constant leaching from the rains (Gardiner and Miller 2004, Schembre 2009).

Cloudbridge's history is similar to the rest of Costa Rica's; cypresses were planted around agricultural fields and remain in parts of the reserve marking the edges of long gone pastureland and lining the sides of old mountain roads. Cypress were initially used to reforest the same fields after the area became a reserve, but many have since been removed and used as lumber to build parts of the reserve's buildings. Current reforestation efforts do not utilize the cypress, and apart from a brief foray into agroforestry in the latter end of the last decade, no more have been planted on the Reserve. However, there are still quite a few large old stands growing, and the potential side affects of this species' growth have gone unstudied.

The purpose of this study was to assess: 1) the potential for *C. lusitanica* to cause significant changes in soil chemistry, namely pH and macronutrient concentrations, and 2) the cypress' invasive potential. Stands of cypress on the southern half of the Reserve (**Figure 1**) were analyzed and compared to native species occupying the same niche, as well as soil samples from open ground.

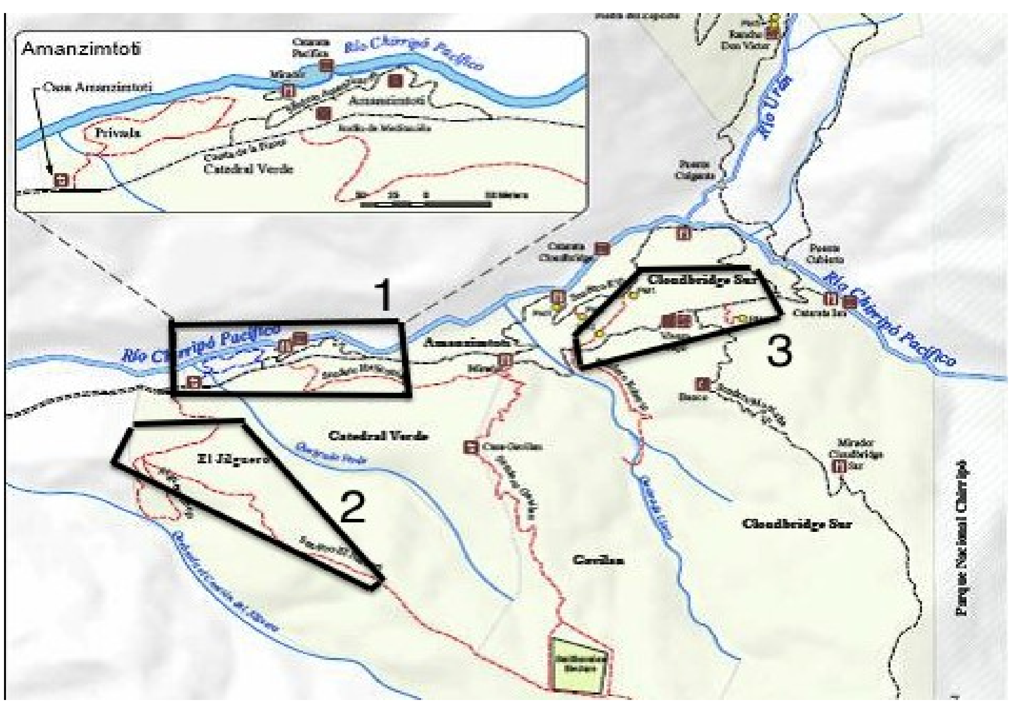



***Figure 1:*** *Map showing Cloudbridge Nature Reserve. Main trails are the fine black lines, side trails are in red, and streams and rivers are in blue. Sampling areas were in Cloudbridge Sur along the Amanzimtoti (1), El Jilguero (2), and Cloudbridge Sur (3) trails.*

# METHODS

### *Sample Location*

An initial survey of *C. lusitanica* locations across the reserve found three separate stands of the trees, two in Cloudbridge Sur and one in Cloudbridge Norte. The two stands in Cloudbridge Surf were divided into three groups based on location, and the soil types listed in (Schembre 2009). The western low elevation group was named Amanzimtoti and the highland group Jilguero, after the trails that go through them. The eastern group became Sur, while the last stand of cypress from Cloudbridge Norte was excluded from the study due to its difficult off-trail location and the prevalence of pit vipers in the area.

After ten cypresses were selected and marked with GPS in each area, further surveys were conducted to find native trees for comparison. Amanzimtoti and Jilguero both are home to the elm, *Ulmus mexicana,* while Sur has very few elms but a prevalence of alders, *Alnus accuminata*. It was decided that both trees would be used for comparison and that the sites would be analyzed separately should the elms and alders be found to have significantly different topsoils under their canopies.

Ten native comparison trees were selected and marked with GPS for each area. For the 'open' points, 10 evenly spaced points along each site's major trail were selected and marked based section 2.1 Soils In-Situ sampling methods of the Sampling and Analysis Protocol of the Ontario Ministry of Agriculture, Food, and Rural Affairs, and Ministry of Environment (Ontario 2012).

### *Sample Collection*

About a quarter cup of topsoil was collected from four spots (upslope, downslope, and on either side) around the base one foot away from the trunk of each tree (Ontario 2012). For open points the same amount was collected from two spots one foot away from either side of the trail. In areas where this was made impossible due to trees bordering trails or cliffs, only three or sometimes two samples were taken to equal a quarter cup of soil.

The samples were put into clean ziplock bags and labeled with their site, species, and sample number corresponding with their GPS label (ex. Amanzimtoti *Cupressus* number 5 would be [AC5]). Each tree's DBH was taken and the number of saplings within viewing distance (approximately 20 meters) was noted. As instructed in the Worth Gardening Soil Testing Kit pamphlet, the bags of soil were cleaned of organic matter and rocks via sieve and allowed to air dry in the lab until chemical sampling took place (Worth Gardening 2016).

### *Chemical Testing*

After drying the soils were transferred to sealable plastic containers, saturated with deionized water, and left to settle overnight as instructed by (Worth Gardening 2016). This water was used in conjunction with the Worth Gardening soil test kit to determine the pH and concentrations of nitrogen, phosphorus, and potassium in the soil.

The test kit was not accurate enough to provide true quantitative concentration results for the macronutrients, but it did provide qualitative results in the form of categorical values that apply to ranges in parts per million for each macronutrient (Peaceful Valley Farm Supply 2004), which are listed in **Table 1**. The readings for pH, however, came in the standard one to fourteen scale of acid to base.

| Value | # | N (ppm) | P (ppm) | K (ppm) |
|---|---|---|---|---|
| High | 5 | 20-25 | 120-150 | 360-450 |
| High-Med | 4 | 15-19 | 90-119 | 270-359 |
| Medium | 3 | 10–14 | 60-89 | 180-269 |
| Med-Low | 2 | 5–9 | 30-59 | 90-179 |
| Low | 1 | 0-4 | 0-29 | 0-89 |

**Table 1:**
*The parts per million concentration ranges of each macronutrient in relation to the categories given by the soil kit.*

### *Statistical Analysis*

After finding the overall means for each factor (pH, macronutrient concentrations, potential sapling count, and DBH for cypresses, comparison trees, and 'open' samples), ANOVA tests were used to compare the chemical and sapling data between species and between sites for significant variations. These tests were followed by Tukey HSD (honest significant difference) tests to determine which groups significantly differed from each other. A linear regression was done to see if pH and DBH were at all linked for the three species measured.

# RESULTS

**Soil Chemistry**

No significant differences were found between species or sites for concentrations of nitrogen ($F(2,87)=0.92$, $p=0.40$), phosphorus ($F(2,87)=0.13$, $p=0.88$), or potassium ($F(2,87)=0.13$, $p=0.88$). All were found, on average, to have low levels of nitrogen and medium to high-medium levels of phosphorus and potassium.

The pH readings, however, showed significant variations among sites and by species ($F(8, 81)=5.91$, $p=6e-06$). As a whole, the mean and median pH of the three sites were 6.26 and 6.5 respectively, while the means and medians by site were: 6.52 and 7 for Amanzimtoti [A], 6.28 and 6.5 for Jilguero [J], and 5.98 and 6.25 for Sur [S]. The averages for each sample type (cypress, Alnus/Ulmus, Open) are listed in **Table 2**.

In each location the soil samples adjacent to the cypresses were about one point, or ten times, more basic than the soils around the comparison trees, the elms and alders. The 'Open' samples are more variable, ranging from more acidic to more alkaline in comparison with the other groups in their area. These patterns and the ranges of data that produced these averages are all illustrated below in **Figure 2**.

**Table 2:**
*The mean pH for each group within the three sites listed by site (Amanzimtoti 'A', Jilguero 'J', Sur 'S') then species (*C. lusitanica *'C',* U. mexicana *'U',* A. accuminata *'A'), so here 'AC' is the Amanzimtoti cypresses*
.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| AC | AO | AU | JC | JO | JU | SC | SO | SA |
| 7.3 | 5.8 | 6.5 | 7 | 6 | 6 | 6.3 | 6.3 | 5.4 |

A weak, but significant, positive linear relationship was found between cypress DBH and pH, as is shown in **Figure 3,** but this relationship did not extend to the elms or alders.

**Potential Saplings**

No significant difference was found between the number of saplings surrounding the sampled species ($F(5,54)=2.26$, $p=0.06$). In all but one case the alders showed no signs of successful reproduction. However, in stands of elms and cypresses that had managed to produce offspring, there were large variations in the number of saplings. Overall, most trees did not have any nearby young trees or saplings that could be attributed to their reproduction. The mean number of saplings for each tree type was around two, but this is due to outliers with greater than ten potential saplings which skewed the data.

***Figure 2:***
*The means and ranges in pH for each sample type, cypresses 'C' in green, the elms and alders 'D'( for different) in gold, and the open sites 'O' in blue. The types are also divided by site (Amanzimtoti 'A', Jilguero 'J', and Sur 'S'), so 'CA' stands for the Amanzimtoti cypresses.*

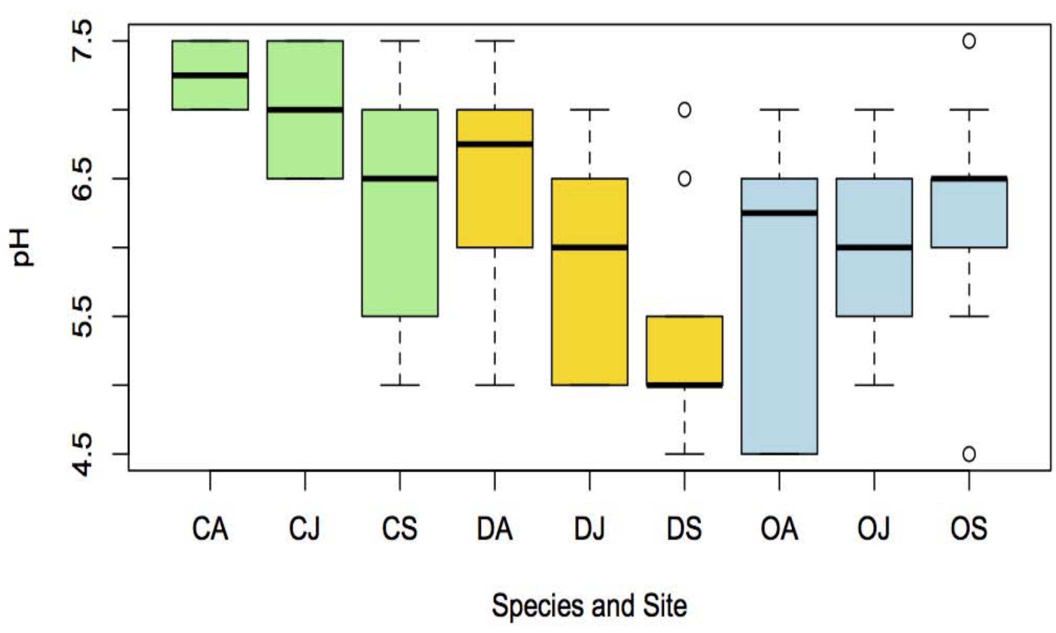


***Figure 4:***
*The means and ranges in number of observed potential saplings by site (Amanzimtoti 'A', Jilguero 'J', Sur 'S') then species (*C. lusitanica *'C',* U. mexicana *'U',* A. accuminata *'A'), so here 'AC' is the Amanzimtoti cypresses.*

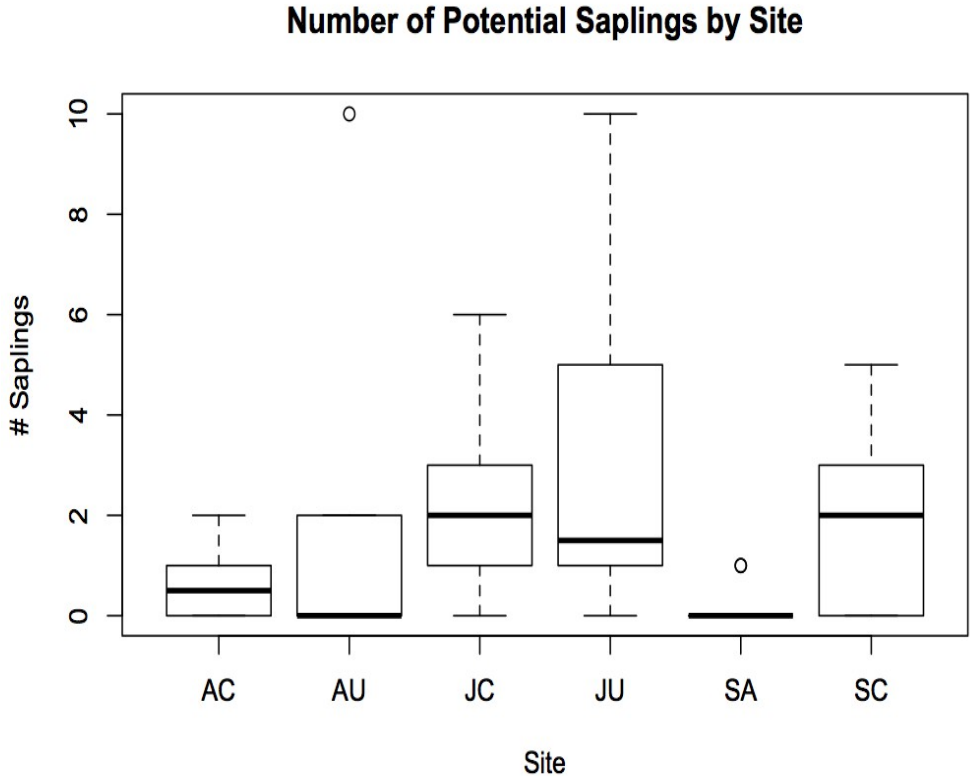
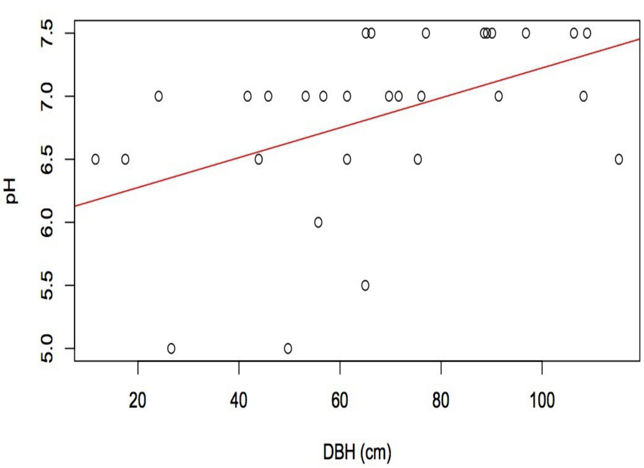



***Figure 3:***
*The linear relationship between DBH and pH in cypresses ($R^2$=0.22, F(1,28)=7.82, p=0.009).*




The median number of potential saplings for each stand of trees is much closer to zero except for the cypresses in the Sur area, which were by far the most consistently successful reproducers. The cypresses in the Sur area had a median value which equaled their mean of two. Each groups mean and median is listed in **Table 3** and their spread is shown in **Figure 4**.

**Table 3:**
*Each sample, listed by site (Amanzimtoti, Jilguero, Sur) then species (Cupressus, Ulmus, Alnus), with their mean and median number of potential saplings surrounding the average sample tree. The means tend to be higher than medians due to occasional very high outliers with many potential saplings that skew the data.*

| | AC | AU | JC | JU | SC | SA |
|---|---|---|---|---|---|---|
| Mean | 0.6 | 1.5 | 2.1 | 3.2 | 1.9 | 0.2 |
| Median | 0.5 | 0 | 0 | 1.5 | 2 | 0 |

# DISCUSSION

**Soil Macronutrient Concentrations**

While there was no significant difference in soil N, P, or K concentrations adjacent to *C. lusitanica*, *A. accuminata*, *U. mexicana*, or open ground, there is reason to be skeptical of the results. Firstly, the relatively high phosphorus and potassium levels found across the reserve are quite unexpected given the soil types they come from. Generally these soils are expected to be undeveloped and leached from the constant rains the cloud forest experiences and therefore have lower phosphorus and potassium concentrations (Schembre 2009, Gardiner and Miller 2004). To have such consistently high values is unusual to the point of casting doubt upon their accuracy.

Secondly, the suggested methods for nitrogen sampling in the Worth Gardening pamphlet contradict the methods suggested in the Ontario Sampling and Analysis Protocol pamphlet section 2.4 Field Quality Control (QC) (Ontario 2012). It is suggested by the Ontario protocol that samples being tested for nitrogen be kept below 10 degrees Centigrade, while no such suggestion is made by Worth Gardening. This may be irrelevant, as the results obtained by the Worth methods are consistent with what should be expected in this environment, but it does seem odd that something as delicate as nitrogen sampling could be accurately obtained with such consumer grade methods.

Overall, the tools provided by Worth Gardening are meant to be used in an individual consumer environment. They lack the accuracy and consistency to be truly acceptable in a scientific setting. In future experiments, soil nutrient sampling should be done in a lab.

**Soil pH**

There was a significant difference between the pH of soil samples under *C. lusitanica, A. accuminata*, *U. mexicana*, and 'open' ground. The soil samples under the cypresses were consistently one point more alkaline than the soil under the comparison species. This is inconsistent with the general idea that confers tend to make soils more acidic.

In the scientific literature, the relationship between conifers and soil pH is somewhat tenuous or unclear (Wilcox and Davenport 1995). Often it is found that in areas of alkaline soils conifers offer remediating effects through their acidity (Cavelier and Tobler 1998, Lemenih 2004), but this would not be beneficial in the already naturally acidic soils of the cloud forest.

A study done on *Juniperus*, a different genus in the same family as the cypress, found that though the young trees made the soil acidic, the more developed canopies of older trees had significantly higher pH (Doescher et al, 1987.) This suggests that the more developed canopies of older junipers may result in higher soil pH levels.

The linear relationship found between cypress pH and DBH on the reserve could be an indicator that this is the case with the cypresses at Cloudbridge as well. Most of the cypresses measured at Cloudbridge are quite old, for they were planted by the first settlers before the reserve existed. The smaller trees, which can be assumed to be younger, on average had more acidic soils, on par with the averages found under comparison trees around the reserve, while the largest old cypresses were almost all neutral to alkaline.

It is not clear why this is the case, and it is most likely due to a variety of factors. The cypress' dense foliage blocks out light and prevents understory growth (Bol and Vroomen 2008), and it could be that this coverage also reduces the amount of runoff and leaching that the soils experience thereby raising the pH of the soil. However, it may be that the lack of understory beneath the cypress stands is due to the higher pH of the soil. Most of the plants that naturally grow in the cloud forest are adapted to the low pH that is standard in the region. A patch of neutral or even alkaline soil is a disturbance to this environment, and may make it more difficult for native plants to grow.

Alternately, it could be that the cypress' leaves and bark simply have a certain pH and they confer it onto the land through deposition and decomposition over time, regardless of the soil's original pH. This would give the appearance of making soils more acidic in areas where the soils are naturally more neutral to basic while also making the soils more alkaline in more acidic environments as seen on the Reserve. More tests on material from the trees themselves would be needed to test this theory.

There is also the possibility that the pH tests used were simply inaccurate. However, the average reserve wide pH value found is within the expected range when compared to a previous study at Cloudbridge (Schembre 2009), duplicate tests tended to be consistent, and the control tests on tap water and deionized water pH came up with expected values.

There is also the possibility that the test tubes were contaminated by the tap water during cleaning, as the tap water here comes from the naturally basic streams (Souers 2004), but this explanation does not hold up as the comparison trees and open samples both came up with more typical acidic results with the same methods.

**Saplings**

*C. lusitanica* was not found to reproduce more than the native comparison species. Though many of the cypress trees did appear to have reproduced successfully at some points, their numbers were roughly similar to the new elms that have grown. The planted cypresses here are generally decades older than the planted elms, so if they were really reproducing at the same rate we would expect many more of them.

All three species sampled in this study are pioneer species, meaning that they colonize open areas caused by disturbances like farming or landslides. As Cloudbridge's reforestation efforts progress, less areas are left open for pioneer species to grow, so it is not likely that any of these species will be more successful at reproduction at Cloudbridge as time goes on.

**Invasive Potential**

Based on the stands of cypress on the Reserve, it is not likely that the cypress will become invasive at Cloudbridge. Invasiveness in conifers is quantified by their Z factor, which is calculated based on seed mass, minimum time to maturity, and time between large seed crops (Richardson and Rejmánek 2004). According to their work, *C. lusitanica* has a Z of greater than or equal to 5.5, which puts it in the same category as other invasive conifers. However, *C. lusitanica* is not listed as invasive in any publication, it is listed as a much less threatening naturalized species.

This is consistent with what is observed at Cloudbridge. Though the cypress is capable of maintaining small populations, it is in no way taking over Costa Rica. In Sur, the area with the most potential cypress saplings, a great deal of the young trees had died. Having a high theoretical invasive score does not matter much if saplings do not ever make it to maturity. Moreover, cypresses are easily wounded by the windstorms that occasionally pass through (one tree I had marked for study fell over completely in March), making their presence here even more tenuous (Lehmann 2006).

# CONCLUSION

In all, *C. lusitanica* does not pose a major threat to the Reserve. It does have an affect on the soil chemistry and this may contribute to the lack of understory underneath most specimens, but their inability to spread in a significant manner makes them relatively harmless compared to other introduced species. Should it ever become a concern that the cypress is spreading or causing significant ecological damage it would be advisable to have this study redone with proper lab equipment.

It would not be advisable to plant more cypresses, of course, but Cloudbridge has not considered planting more cypress in at least the last decade. With the continued regrowth of the natural forest on the reserve filling up any holes that the cypress could have colonized, and the loss of the current cypresses on the reserve to logging for construction and to damage from windstorms, the Cloudbridge cypress population will most likely have ceased to be in the next thirty to fifty years

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